520 Rec'd PCT/PTO 18 APR 2000

FORM PTO-1390 (REV. 5-93)

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER
2345/119

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)
09/529700

INTERNATIONAL APPLICATION NO.
PCT/EP98/06144

INTERNATIONAL FILING DATE
(28.09.98)
28 September 1998

PRIORITY DATE CLAIMED.
(18.10.97)
18 October 1997

TITLE OF INVENTION
SEMICONDUCTOR LASER CHIP

APPLICANT(S) FOR DO/EO/US
RICHTER, Hartwig; and BECKER, Manfred

Applicants herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report and International Preliminary Examination Report.

EXPRESS MAIL NO. EL179106520US

U.S. APPLICATION NO if known, see 37 C.F.R 1.5 09/529700	INTERNATIONAL APPLICATION NO PCT/EP98/06144	ATTORNEY'S DOCKET NUMBER 2345/119

422 Rec'd PCT/PTO 18 APR 2000

17. ☒ The following fees are submitted: | CALCULATIONS | PTO USE ONLY

Basic National Fee (37 CFR 1.492(a)(1)-(5)):

Search Report has been prepared by the EPO or JPO $840.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) ... $670.00

No international preliminary examination fee paid to USPTO (37 CFR 1 482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) $760.00

Neither international preliminary examination fee (37 CFR 1 482) nor international search fee (37 CFR 1 445(a)(2)) paid to USPTO $970.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $96 00

ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 840.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	18 - 20 =	0	X $18.00	$ 0	
Independent Claims	1 - 3 =	0	X $78.00	$ 0	
Multiple dependent claim(s) (if applicable)			+ $260.00	$ 0	
TOTAL OF ABOVE CALCULATIONS =				$ 840.00	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$ 840.00	
Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 840.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$ 840.00	
				Amount to be refunded	$
				charged	$

a. ☐ A check in the amount of $__________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of **$840.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Kenyon & Kenyon
One Broadway
New York, New York 10004

[signature]
SIGNATURE

Richard L Mayer, Reg No. 22,490
NAME

4/18/00
DATE

274795

09/529700

422 Rec'd PCT/PTO 18 APR 2000

EXPRESS MAIL CERTIFICATE

"EXPRESS MAIL" MAILING LABEL NUMBER EL179106520US

DATE OF DEPOSIT 4/18/00

TYPE OF DOCUMENT National Application

SERIAL NO. ____________ FILING DATE Herewith

I HEREBY CERTIFY THAT THIS PAPER OR FEE IS BEING DEPOSITED WITH THE UNITED STATES POSTAL SERVICE "EXPRESS MAIL POST OFFICE TO ADDRESSEE" SERVICE UNDER 37 CFR 1.10 ON THE DATE INDICATED ABOVE, BY BEING HANDED TO A POSTAL CLERK OR BY BEING PLACED IN THE EXPRESS MAIL BOX BEFORE THE POSTED DATE OF THE LAST PICK UP, AND IS ADDRESSED TO THE ASSISTANT COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20231.

BORIS POLANCO

(TYPED OR PRINTED NAME OF PERSON MAILING PAPER OR FEE)

(SIGNATURE OF PERSON MAILING PAPER OR FEE)

09/529700
422 Rec'd PCT/PTO 18 APR 2000
[2345/119]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICANT: RICHTER, et al.

SERIAL NO.: to be assigned

FILED: herewith

TITLE: SEMICONDUCTOR LASER CHIP

ART UNIT: not yet known

EXAMINER: not yet known

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

PRELIMINARY AMENDMENT

Please amend the above-identified application before a first consideration on the merits as follows:

IN THE TITLE

Please amend the title to read --SEMICONDUCTOR LASER--.

IN THE SPECIFICATION

On page 1, before the title, delete "SPECIFICATION".

On page 1, before line 1 insert --Field of the Invention--.

On page 1, line 1, change "chip according to the definition" to --in general, and, particular, to a semiconductor laser including a semiconductor laser chip and at least one temperature sensor secured directly to or integrated in the semiconductor laser chip--.

On page 1, delete line 2.

On page 1, before line 4, insert --Related Technology--.

EL179106520

On page 1, line 5, change "Dr. Richter" to --H. Richter-- and change "referred to and discussed at the end" to --"*Chips mit Zukunftspotential*" [Chips with Future Potential], interim results of the Telekom Research Project OEIC, TelekomVision 7/93, pp. 41 through 47, which is hereby incorporated by reference herein--.

On page 2, line 15, before "path" insert --circuit--.

On page 2, line 18, before "DE" insert --No.--.

On page 2, line 19, change "EP 0 779 526" to --No. EP 0 779 526, which are hereby incorporated by reference herein,--.

On page 2, line 21, change "this publication" to --European Patent No. EP 0 779 526--

.

On page 2, line 27, before both occurrences of "DE" insert --No.--.

On page 2, line 29, change "already explained" to --noted above--.

On page 3, before line 1, insert --Summary of the Invention--.

On page 3, line 1, change "The object" to --An object-- and change "devise" to --provide--.

On page 3, delete lines 7-11.

On page 3, before line 13, insert --The present invention provides a semiconductor laser including a semiconductor laser chip and at least one temperature sensor disposed directly on or integrated in the semiconductor laser chip for measuring an operating temperature.--.

On page 3, line 24, after "are" insert --revealed below.--.

On page 3, delete lines 25-28.

On page 3, before line 30, insert --Brief Description of the Drawings--.

On page 3, line 30, before "invention" insert --present--, delete "now" and change "on the basis of exemplary embodiments. In the" to --with reference to the drawings, in which:--.

On page 4, delete line 1.

On page 4, line 3, after "Figure 1" insert --a schematic diagram of--.

On page 4, line 5, after "Figure 2" insert --a schematic diagram of--.

On page 4, line 8, after "Figure 3" insert --a schematic diagram of--.

On page 4, line 10, after "Figure 4" insert --a schematic diagram of--.

On page 4, line 13, after "Figure 5a" insert --a schematic diagram of--.

On page 4, line 15, after "Figure 5b" insert --a schematic diagram of--.

On page 4, line 17, after "Figure 6" insert --a schematic diagram of--.

On page 4, line 20, after "Figure 7" insert --a schematic diagram of--.

On page 4, line 23, after "Figure 8" insert --a schematic diagram of--.

On page 4, line 26, after "Figure 9" insert --a schematic diagram of--.

On page 4, line 28, after "Figure 10" insert --a schematic diagram of--.

On page 4, line 30, after "Figure 11" insert --a schematic diagram of-- and change "thermo-" to --thermoelement--.

On page 5, line 1, before "Peltier" insert --a--.

On page 5, line 3, after "Figure 12" insert --a schematic diagram of--.

On page 5, line 5, after "Figure 13" insert --a schematic diagram of--.

On page 5, before line 7, insert --<u>Detailed Description</u>--.

On page 5, line 7, change "in the" to --in H. Richter, "*Chips mit Zukunftspotential*" [Chips with Future Potential], discussed above--.

On page 5, delete lines 8-9.

On page 5, line 10, delete "pp. 41 through 47." and change "only" to --typically--.

On page 6, line 12, after "Patent" insert --No. DE--.

On page 8, line 11, change "must be" to --is--.

On page 9, line 10, change "the main application case" to --an embodiment--.

On page 9, line 12, before "measurement" insert --for--.

On page 9, line 14, before "measurement" insert --for--.

On page 9, line 22, change "12 -, to" to --12 - to--.

On page 11, line 1, change "Patent Claims" to --WHAT IS CLAIMED IS:--.

<u>IN THE CLAIMS</u>

Please cancel without prejudice claims 1-15 and add new claims 16-33 as follows:

--16. (new) A semiconductor laser comprising:

a semiconductor laser chip; and

at least one temperature sensor disposed directly on or integrated in the semiconductor

laser chip for measuring an operating temperature.

17. (new) The semiconductor laser as recited in claim 16 wherein the at least one temperature sensor is secured by welding directly on or in the semiconductor laser chip, an energy for the welding coming from a light source.

18. (new) The semiconductor laser as recited in claim 17 wherein the light source includes at least one of a Nd-glass source, a Nd-YAG source and a source having a similar spatial distribution and similar spectral distribution to a Nd-glass source or a Nd-YAG source.

19. (new) The semiconductor laser as recited in claim 17 wherein prior to the welding each of the at least one temperature sensor is sealed into an electrically insulating glass.

20. (new) The semiconductor laser as recited in claim 16 wherein each of the at least one temperature sensor is arranged and secured in a respective hole, each of the respective hole being formed in the laser chip using light-welding.

21. (new) The semiconductor laser as recited in claim 16 wherein the at least one temperature sensor in included in the semiconductor laser chip, wires for measuring an electrical resistance through the semiconductor laser chip being mounted on the semiconductor laser chip.

22. (new) The semiconductor laser as recited in claim 21 wherein the wires for measuring the electrical resistance through the semiconductor laser chip include a pumping current lead wire and an additional wire used as a sensor supply lead.

23. (new) The semiconductor laser as recited in claim 16 wherein the at least one temperature sensor includes a thermoelement.

24. (new) The semiconductor laser as recited in claim 16 wherein the at least one

temperature sensor includes a thermoelement having two wires joined by laser-light welding and secured in a common work step to the semiconductor laser chip.

25. (new) The semiconductor laser as recited in claim 24 wherein a contact surface of a material of one of the wires is deposited on the semiconductor laser chip before the two wires are joined.

26. (new) The semiconductor laser as recited in claim 16 further comprising at least one second semiconductor laser chip forming a semiconductor laser array with the semiconductor laser chip, each of the at least one temperature sensors being disposed directly on or integrated in a respective one of the semiconductor laser chip and the at least one second semiconductor laser chip for measuring a respective operating temperature, an operating temperature of the semiconductor laser array being measurable by measuring the operating temperature of the semiconductor laser chip and of each of the at least one second semiconductor laser chip, a respective output wavelength of the semiconductor laser chip and of each of the at least one semiconductor laser chip being adjustable by varying their respective pumping currents.

27. (new) The semiconductor laser as recited in claim 16 wherein each of the at least one temperature sensor includes a respective thermoelement disposed directly on the semiconductor laser chip, each of the thermoelements being operatable in a reversed operation as a respective Peltier element having a current source for adjusting a respective temperature with local selectivity.

28 (new) The semiconductor laser as recited in claim 27 wherein the semiconductor laser chip includes an active laser zone having at least one measuring point for measuring a wavelength of the semiconductor laser chip so as to enable an adjusting of the wavelength.

29. (new) The semiconductor laser as recited in claim 28 wherein the semiconductor laser is included in a telecommunications laser and the semiconductor laser chip includes one measuring point in the active zone.

30. (new) The semiconductor laser as recited in claim 28 wherein the semiconductor laser is included in a high-performance laser and the semiconductor laser chip includes a plurality of measuring points along the active laser zone.

31. (new) The semiconductor laser as recited in claim 27 wherein the at least one temperature sensor includes at least two thermoelements operated and configured in a cascade arrangement.

32. (new) The semiconductor laser as recited in claim 16 wherein the measured operating temperature is used in a closed-loop control circuit including a setter for adjusting the operating temperature.

33. (new) The semiconductor laser as recited in claim 16 further comprising a respective temperature setter and a respective temperature controller associated with each of the at least one temperature sensor and disposed on the semiconductor laser chip.--.

IN THE ABSTRACT

Please replace the abstract with the following new abstract:

--In a semiconductor laser, at least one temperature sensor is disposed directly on or integrated in a semiconductor laser chip for measuring an operating temperature. Precisely and/or locally solved measurement of the operating temperature of the laser are possible. One or more temperature sensors may be placed and fastened directly onto the laser chip or in a hole of the laser chip by welding, especially with Nd-YAG-laser light or light with similar characteristics. Fine equalization of temperature may be carried out, for example, by Peltier elements, components of the Peltier elements being mounted directly onto the laser chip. A cascaded arrangement of thermoelements and Peltier elements on a laser chip is also provided for.--.

REMARKS

This Preliminary Amendment cancels original claims 1-15 in the underlying PCT Application No. PCT/EP98/06144 and adds new claims 16-33. The new claims do not add new matter to the application but do conform the claims to U.S. Patent and Trademark Office rules.

The amendments to the specification and abstract are to conform the specification and abstract to U.S. Patent and Trademark Office rules. It is respectfully submitted that the amendments to the specification and abstract do not introduce new matter into the application.

The underlying PCT application includes a Search Report, a copy of which is included herewith.

Conclusion

Consideration of the present application as amended is hereby respectfully requested.

Respectfully Submitted,

Kenyon & Kenyon

Dated: 4/18/00

By: [signature]

Richard L. Mayer
(Reg. No. 22,490)

One Broadway
New York, NY 10004
Tel. (212) 425-7200
Fax. (212) 425-5288

7/PRT1
09/529700
422 Rec'd PCT/PTO 18 APR 2000
[2345/119]

SPECIFICATION

SEMICONDUCTOR LASER CHIP

The present invention relates to a semiconductor laser chip according to the definition of the species in Claim 1.

Semiconductor lasers are generally known, as proceeds, for example, from the publication by Dr. Richter, TelekomVision 7/93, referred to and discussed at the end of this document.

The application of such a laser is described in detail in the publication by K. H. Park, "Fabrication and Transmission Experiments of Distributed Feedback Lasers Modules for 2.5 Gb/s Optical Transmission Systems" published in Optical and Quantum Electronics 27 (1995), 547-552. To further enhance capacity, optical carrier frequency technologies, also referred to as wavelength division multiplex systems, are increasingly being used. The output wavelength of the semiconductor lasers used in these systems must be able to be adjusted and corrected within a very narrow range. Manipulated variables used for this purpose include the externally adjusted temperature of the laser carrier, and the laser's pumping power.

At a constant pumping power, an incorrect determination of the temperature of the laser chip leads to deviations in the output wavelengths, particularly when it is necessary to change the pumping power for operational reasons. The reasons for a change in pumping power can be unplanned, such as the effects of ageing on the laser, or also planned, such as changing the laser's output power in response to a change in path attenuation, or subsequent to a reconfiguration in switched networks (routing, equivalent line circuit).

While in telecommunications lasers the emphasis is on a monomode characteristic and a

EL149106520

small line width, as well as a rapid modulability, for purposes such as material processing, it is important that the semiconductor laser have a high power output. In comparison to telecommunications lasers, high-performance lasers are often very long (up to 2 mm). Unavoidable irregularities due to manufacturing, along the active laser zone, lead to local temperature peaks, particularly in operations entailing the highest power outputs. Such irregular temperature distribution results in a diminished output power and, in the extreme case, to irreversible degradation of the laser.

In known methods heretofore, a laser's temperature is only measured at one location, namely at its laser carrier being used as a heat sink. When measuring the temperature, errors can occur due to the heat transfer resistance between the laser chip and the heat sink, and also due to the finite thermal conductivity of the laser chip material; in addition to this such errors are caused by other heat sources produced by the bulk resistances in the pumping current's path. Besides the steady-state temperature measuring errors, large time constants also result, which adversely affect temperature control. In known methods heretofore, irregularities in the temperature characteristic were not recorded at all in the case of high-performance lasers. German Patent DE 19 546 443 and European Patent EP 0 779 526 describe an optical and/or electro-optical connection, and a method for manufacturing such a connection for two optical and/or electro-optical components. Figure 7 of this publication, in particular, shows how a pump-current lead wire is secured in a semiconductor laser, and provides details of the same in the corresponding description. It also describes how a hole can be bored into a laser chip using laser welding light.

Other laser chips or semiconductor laser modules are fundamentally described in German Patent DE 42 32 326 and in German Patent DE 42 32 327.

As already explained, it is customary for the temperature of a laser to be measured at only one location, namely at its laser carrier being used as a heat sink.

The object of the present invention is to devise an arrangement of a temperature sensor or of a plurality of temperature sensors, which will enable a more precise and/or locally resolved measurement of the operating temperature, it also being possible to implement a precise temperature adjustment with substantial accuracy and/or local selectivity.

The achievement of this objective in accordance with the present invention is characterized in the characterizing part of Claim 1.

Further refinements of the present invention or features are characterized in Claims 2 through 15.

A very high precision, not attainable in known methods heretofore, is achieved by securing one or a plurality of temperature sensors directly onto the laser chip, and in intimate connection with the same, in a welding operation using Nd-YAG laser light or light having similar properties. The fine temperature adjustment is advantageously carried out using Peltier elements, the components of the Peltier elements being applied directly to the laser chip using Nd-YAG laser light. In accordance with the present invention, the wavelength of the laser chip is measured and, when necessary, the wavelength of the laser chip is also adjusted, the telecommunications lasers having one measuring point per active laser zone, and the high-performance lasers having a plurality of measuring points per laser chip along the active laser zone.

Other advantages, features, and possible applications of the present invention are revealed in the dependent claims, as well as in the following description, in conjunction with the drawings. The terms and reference numerals included in the appended list of reference numerals are used in the Specification, Patent Claims, in the Abstract, and in the Figures.

The invention shall now be elucidated on the basis of exemplary embodiments. In the drawings, the figures show:

Figure 1 a semiconductor laser chip in accordance with the related art;

Figure 2 an arrangement and mounting of a known sensor on the laser chip;

Figure 3 a sensor encapsulated in glass;

Figure 4 a semiconductor laser chip having a hole bored by laser welding light;

Figure 5a an arrangement having a bulk resistor as a sensor;

Figure 5b an arrangement having a symmetrical sensor;

Figure 6 a representation of the bulk resistance in parallel to the pumping current circuit;

Figure 7 an arrangement for measuring the temperature of individual lasers using bulk-resistance sensors;

Figure 8 an arrangement for measuring temperature irregularity using bulk-resistance sensors;

Figure 9 a thermoelement mounted on a laser chip;

Figure 10 a thermoelement having only one additional wire;

Figure 11 an arrangement for regulating temperature using a thermo- and Peltier element;

Figure 12 a cascaded arrangement of thermoelements on a laser chip; and

Figure 13 an arrangement for locally selective temperature regulation.

Figure 1 shows the design of a known laser chip, as described, for example, in the essay, "*Chips mit Zukunftspotential*" [Chips with Future Potential], interim results of the Telekom Research Project OEIC, by Dr. Hartwig Richter in TelekomVision 7/93, pp. 41 through 47. Up until now, a laser's temperature has only been measured at one location, namely at its laser carrier that is used as a heat sink. In this context, a temperature sensor 1, together with its lead wires 2 and 3, is mounted on heat sink 6. Semiconductor laser chip 4, also referred to simply as laser chip, receives a pumping current at its active laser zone 5 via wires 7 and 8 that supply the pumping current. As already described at the outset, an arrangement of this kind has the following disadvantages: the difference between the temperature of semiconductor laser chip 4, which is also determinative for the output wavelength of the laser, and the externally adjusted temperature of heat sink 6, is not recorded. The temperature difference is caused by the heat transfer resistances between laser chip 4 and the laser carrier or heat sink 6, as well as by the finite thermal conductivity of the laser chip material. The bulk resistances in the pumping current circuit are also a source of heat. The result is not only steady-state measuring errors of temperature, but large time constants as well, which have an adverse effect on a temperature control.

Figure 2 illustrates how an already known temperature sensor 1 can be applied by welding using laser light to laser chip 4. The remaining design of the arrangement according to Figure 2 corresponds to that of Figure 1. Melting points 10 formed using this welding method secure temperature sensor 1 to laser chip 4, as shown in Figure 3. According to the specific requirements, it can be necessary and/or also advantageous to encapsulate temperature sensor 1, before applying it to laser chip 4, in a thermally conductive, easily weldable material 9, for example glass, as shown in Figure 3. The remaining design corresponds again to that already described previously, however heat sink 6 of semiconductor laser 4 is not

shown, since the intention here is to merely show the arrangement of an encapsulated temperature sensor 1.

Figure 4 depicts such a temperature sensor 1 in a predrilled hole. Shown here, again, is laser chip 4 having wire 8 for supplying pumping current, as well as wires 2 and 3 for suppling measuring current to temperature sensor 1. Also shown, are wires 2 and 3 for supplying measuring current to temperature sensor 1.

To produce the hole for temperature sensor 1 in laser chip 4, laser light radiation can likewise be used, as described in German Patent 19 546 443.

At this point, it should be remarked that the described method for arranging one or a plurality of temperature sensors, as well as the fine temperature adjustment characterized by high precision and/or local selectivity with respect to temperature is easily applicable to laser chips of thermally isotropic material.

The arrangements in accordance with Figures 5a, 5b and 6 enable the temperature dependency of bulk resistor 11 itself to be measured. The resistor is apparent between the two melting points 10, where the two wires 2 and 3 for supplying measuring current are mounted by welding or another method, for example bonding. Also shown are lead wires 2 and 3 for the measuring current and lead wire 8 for the pumping current.

Figure 5b shows an arrangement having symmetrical sensors, individual laser 5 being configured symmetrically between melting points 10 in laser chip 4. Here, bulk resistor 11 is again disposed between the two measuring points 10.

Figure 6 illustrates that bulk resistor 11 is arranged in parallel to the pumping current circuit, here again, heat sink 6 being connected to laser chip 4 by melting points 18 formed during welding. Heat sink 6 is connected by a wire 7 for supplying the pumping current, and

individual laser 5 is likewise connected by a wire 8 for supplying the pumping current. Wire 3 is connected to melting point 10, to be able to supply the necessary measuring current.

The need is eliminated here for second melting point 10 for wire 2; instead, wire 7 or wire 8 can be jointly used.

Measuring the temperature of individual lasers 5 having bulk-resistance sensors is illustrated in Figure 7. The individual bulk resistors 11 are disposed between melting points 10 of individual lasers 5, which are located on or in a laser chip 4. This demonstrates that when a plurality of individual lasers 5 are configured on one laser chip 4, the temperature of each individual laser 5 can be measured. As a result, it is possible to adjust the output wavelengths of these individual lasers 5 during operation, by way of their pumping currents, without explicitly measuring their wavelength.

A similar technology (Figure 8) makes it possible, when working with high-performance lasers, to measure the temperature distribution along an active-laser zone of an individual laser 5 on or in laser chip 4.

Particular advantages are derived when temperature sensor 1 is a thermoelement. It is then not only possible to secure a previously fabricated thermoelement using laser-light welding, directly onto the measuring object, in close thermal contact with the same, as already described, but it is also possible, in one work step, to join the two individual wires required for the thermoelement, using laser-light welding, to form one thermoelement, and to secure it to the measuring object.

As is evident in Figure 9 from the arrangement of a thermoelement on a laser chip 4, each thermoelement, shown here as measuring point 12, now has one measuring lead wire 2 and one measuring lead wire 3, each of different material.

Before joining wires 2 and 3 on laser chip 4, it is particularly advantageous to vapor-deposit a contact surface 21 on semiconductor laser 4, or to apply it in some other suitable way, this surface 21 either being made of the material of wire 2 or of the material of wire 3 (Figure 9).

At the second place where wires 2 and 3 are united, a second thermoelement 13 is formed. At point 14, a voltage that is dependent upon the temperature difference between points 12 and 13 can then be tapped off; in this context, the measuring instrument at point 14 must be surrounded by wires of the same material. Of course, wires 2 and 3 can also be partially or completely designed as printed conductors that are permanently connected to a chip (e.g., to laser chip 4). Temperature-reference point 13 can be on chip 4 itself, on heat sink 6 of semiconductor laser 4, or even on the housing surrounding the entire arrangement, in accordance with Figure 1.

Figure 10 shows a design variant that makes do with only one additional wire 3, in which the otherwise necessary wire 2 is the pumping-current lead wire 8, made, for example, of gold or copper. The other wire 3 for thermoelement 12 is made, for example, of Konstantan.

A further advantage is derived in a reversed operation by using a thermoelement in accordance with Figure 11 as a Peltier element having a current source 17. Similarly to the measuring arrangement according to Figure 9, here as well, wires 19 and 20 between points 15 and 16 are made of different materials. Depending on the direction of the current from source 17, the heat can be transferred from point 15 to point 16 (main application case: semiconductor laser 4 is cooled) or from point 16 to point 15 (semiconductor laser 4 is additionally heated).

The Peltier element formed from wires 19 and 20 between points 15 and 16 is fabricated using the same technology as thermoelement pair 2, 3, 12, 13, described in Figure 9.

Using a thermoelement pair functioning as a temperature sensor, in accordance with Figure 9, and a Peltier element 15, 16, 19, 20 operated as a temperature setter, one can precisely adjust the temperature of point 15. To reduce control errors, point 15 should be close to point 12. The controller (not shown) then controls current source 17 as a function of measuring voltage 14 of thermoelement pair 12 and 13, measuring point 13 being an external reference point. In this control, it is beneficial for reference point 13 and thermal reference point 16 (in the main application case, a heat sink) of the Peltier element to have the same temperature. This reference location 13 or 16 can be a point outside of the laser housing (measurement as compared to ambient temperature). However, it is also possible for the reference location to be placed on heat sink 6 of semiconductor laser 4 (measurement of the differential temperature with respect to heat sink 6 of semiconductor laser 4, if indicated, with heat dissipation likewise to heat sink 6 of semiconductor laser 4).

If semiconductor laser 4 is a telecommunications laser, then its output wavelength can be very finely tuned.

For very long lasers 4 (for example, high-performance lasers), it is also possible – as shown in Figure 12 –, to configure both thermoelement element pairs 12 and 13, as well as Peltier elements 15 and 16, in a cascade arrangement, to achieve a more homogeneous heat dissipation.

Figure 13 illustrates how the temperature irregularities which limit power output, in particular along the active laser zone 5, can be reduced when working with high-performance lasers, in particular. In a separate controller, each measuring voltage 14 of corresponding measuring point 12 produces its own actuating current 17 for cooling the corresponding heat-dissipation point 15. The dimensional design of the controller is especially simple, when all reference points 13 and all thermal reference points 16 have the same temperature.

When this temperature control that is selective with regard to location is used, it is possible,

for example, to cool especially hot points more intensely than less hot points and, in this manner, achieve a uniform temperature characteristic along the active laser zone 5 of laser chip 4.

Using the technology described here, one can easily conceive of other refinements or arrangements derived from the particular laser chip and its application area, depending on the requirement.

Patent Claims

1. A semiconductor laser comprising an arrangement for measuring operating temperature, characterized in that

at least one temperature sensor (1) is secured directly on or integrated in the semiconductor laser chip (4).

2. The semiconductor laser as recited in the preamble of Claim 1, characterized in that

at least one temperature sensor (1) is secured by welding directly on or in the semiconductor laser chip (4), the energy required for welding coming from a light source, in particular from a Nd-glass source or a Nd-YAG source or from a source having a similar spatial and similar spectral distribution.

3. The semiconductor laser as recited in the preamble of Claim 1 or of Claim 2, characterized in that

prior to the actual welding operation, the temperature sensor (1) is sealed into a highly electrically insulating glass.

4. The semiconductor laser as recited in one of Claims 1 or 2, characterized in that

the temperature sensor (1) is arranged and secured in a hole that is placed in, in particular burned by light-welding into, the laser chip (4).

5. The semiconductor laser as recited in one of Claims 1 through 4, characterized in that

the laser chip (4) itself is designed as a temperature sensor (1), in which additional wires (for example 2 and 3) for measuring the electrical resistance through the semiconductor laser chip (4) (bulk resistor 11; Figure 5a,b) are mounted on the same.

6. The semiconductor laser as recited in Claim 5, characterized in that

mounted on the semiconductor laser chip (4) is only one additional wire (3) which is used, together with a pumping current lead wire (8), as a second sensor supply lead for electrical resistance measurement.

7. The semiconductor laser as recited in one of Claims 1 through 6, characterized in that

the temperature sensor(s) (1) is designed as a thermoelement.

8. The semiconductor laser as recited in one of Claims 1 through 7, characterized in that

the temperature sensor (1) is designed as a thermoelement of two wires, which are joined by laser-light welding and are secured, in the same work step, to semiconductor laser chip (4).

9. The semiconductor laser as recited in Claim 8, characterized in that

before the two wires are joined, a contact surface of the material of the one or other wire is deposited on the semiconductor laser.

10. The semiconductor laser as recited in the preamble of Claim 1, characterized in that

to measure the operating temperature of a semiconductor laser array, the temperature of the individual lasers (5) is measured; and

that their output wavelengths are adjusted by varying their pumping currents.

11. The semiconductor laser as recited in one of Claims 1 through 10, characterized in that

to adjust temperature with local selectivity, the thermoelements arranged on the semiconductor laser chip are operated in a reversed operation as Peltier elements having a current source.

12. The semiconductor laser as recited in Claim 11, characterized in that

the wavelength of the semiconductor laser chip (4) is measured and, when necessary, the wavelength of the laser chip is also adjusted, telecommunications lasers having one measuring point per active laser zone, and high-performance lasers having a plurality of measuring points per laser chip along the active laser zone.

13. The semiconductor laser as recited in Claim 11 or 12, characterized in that

the thermoelements and/or Peltier elements are operated and configured in a cascade arrangement.

14. The semiconductor laser as recited in one of Claims 1 through 13, characterized in that

the measured temperature is used in a closed-loop control circuit having a setter (15) to adjust the temperature.

15. The semiconductor laser as recited in one of Claims 1 through 14, characterized in that

a plurality of temperature sensors and temperature setters, each having one separate temperature controller, are arranged on the semiconductor laser.

Abstract

The invention relates to a semiconductor laser chip, especially temperature probe(s) and temperature regulator(s) (1 or 15) related to chip technology. The invention also relates to the direct arrangement of one or more temperature probes (1) on or in the laser chip (4). Said temperature probe(s) enable(s) a precisely and/or locally solved measurement of the operating temperature of the laser. In addition, a fine equalization of temperature occurs with higher precision adjustment of temperature and/or position selectivity of temperature. To this end, one or more temperature probes (1) is/are placed and fastened directly onto the laser chip (4) or in a hole of the laser chip by means of a welding; especially with Nd-YAG-laser light or light with similar characteristics. The fine equalization of temperature is carried out, for example, by peltier elements, whereby the components of the peltier elements are mounted directly onto the laser chip (4) by means of Nd-YAG-laser light welding. In addition, the measurement of the temperature of the individual lasers (5) is carried out by the measurement of the temperature dependence of the bulk resistors (11). The invention also relates to a cascaded arrangement of thermoelements and peltier elements on a laser chip.

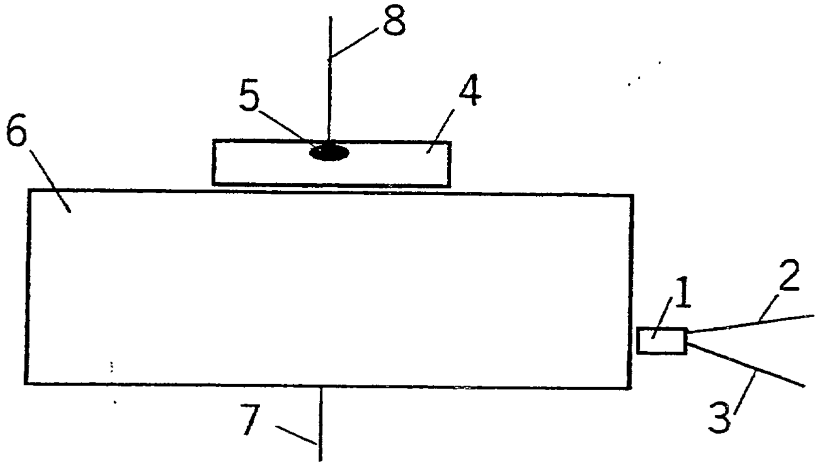

FIG. 1

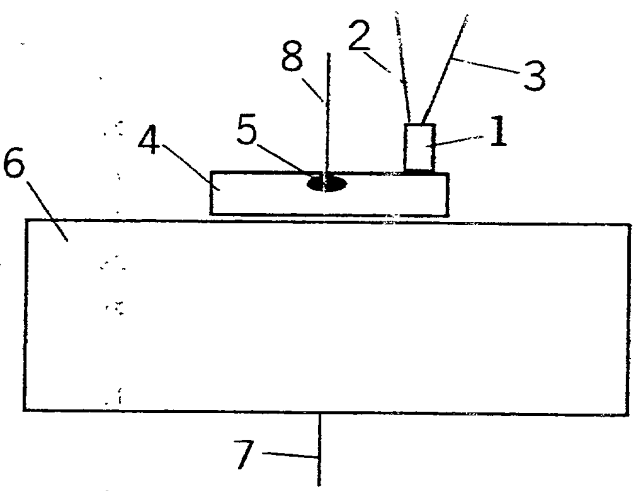

FIG. 2

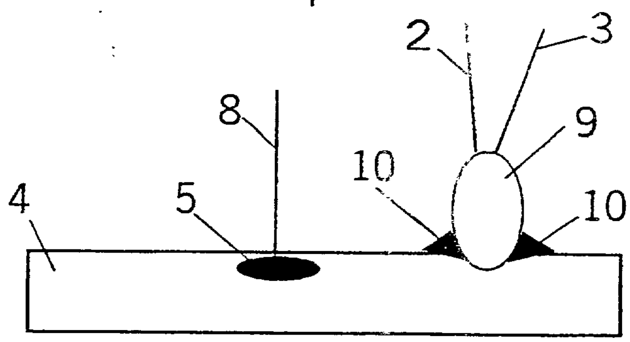

FIG. 3

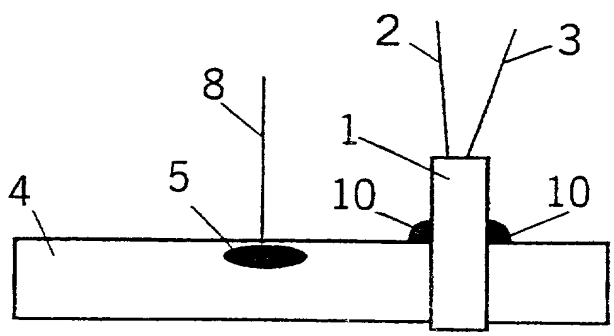

FIG. 4

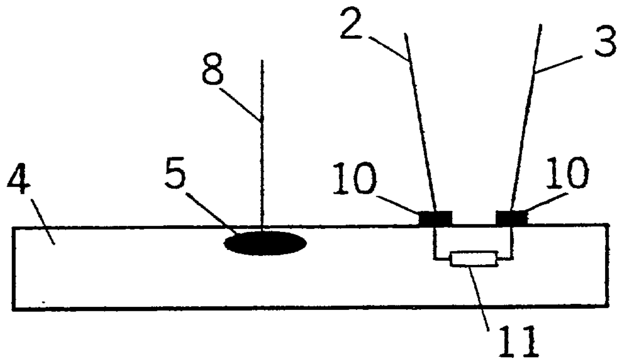

FIG. 5A

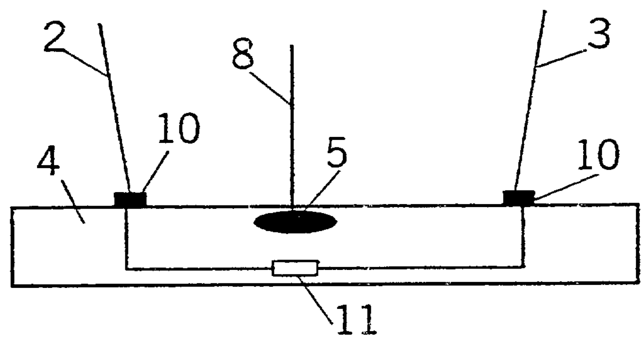

FIG. 5B

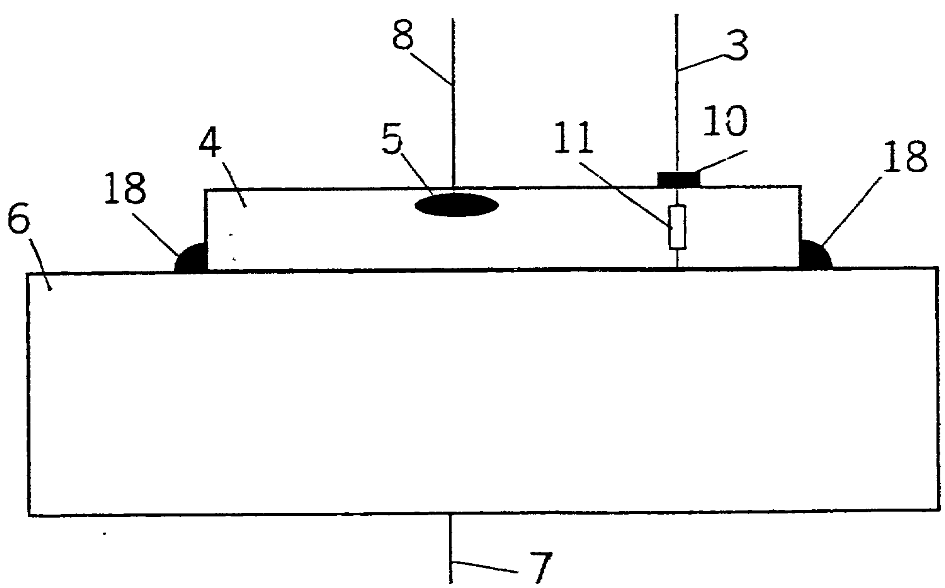

FIG. 6

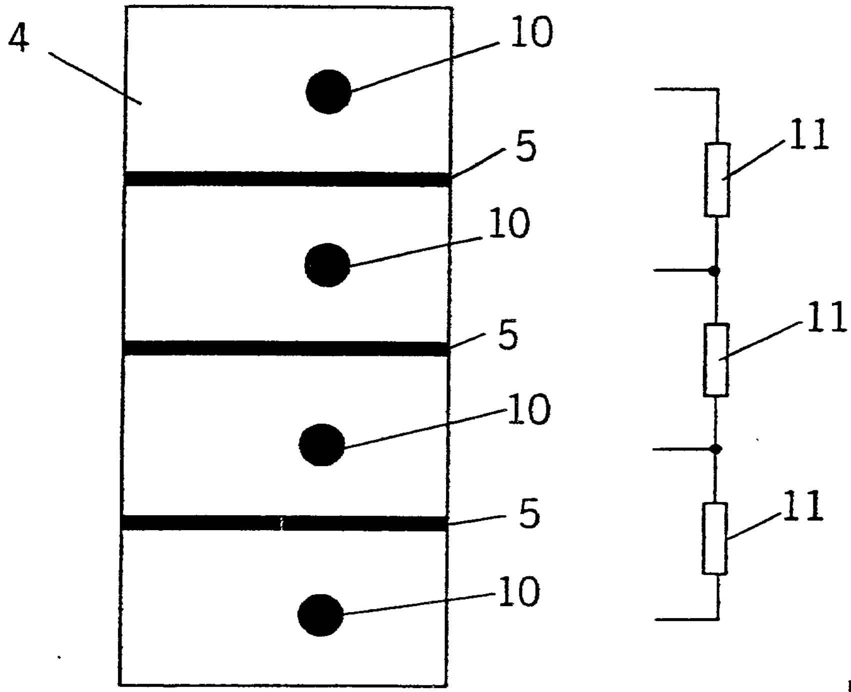

FIG. 7

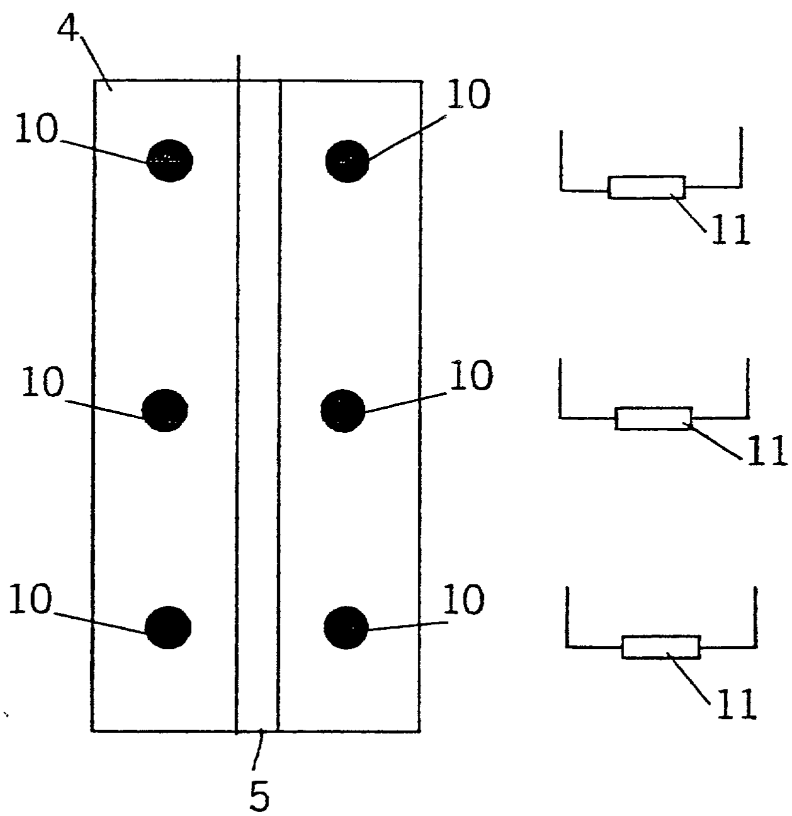

FIG. 8

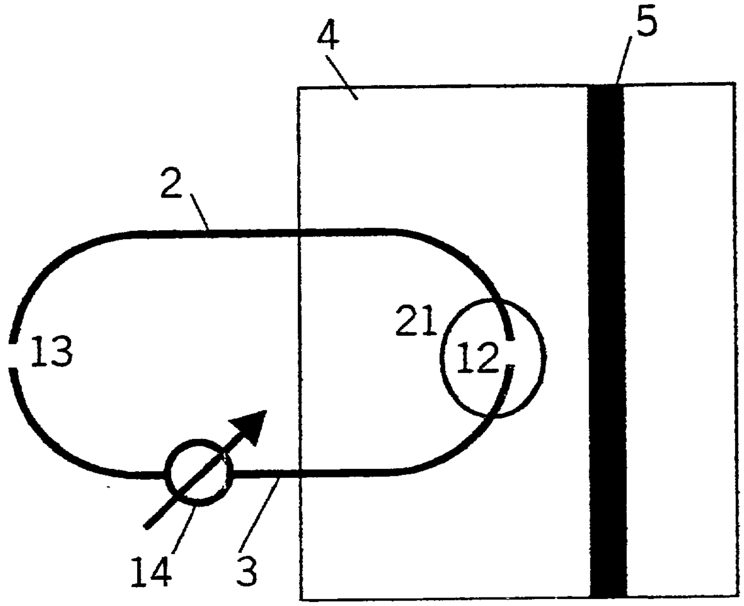

FIG. 9

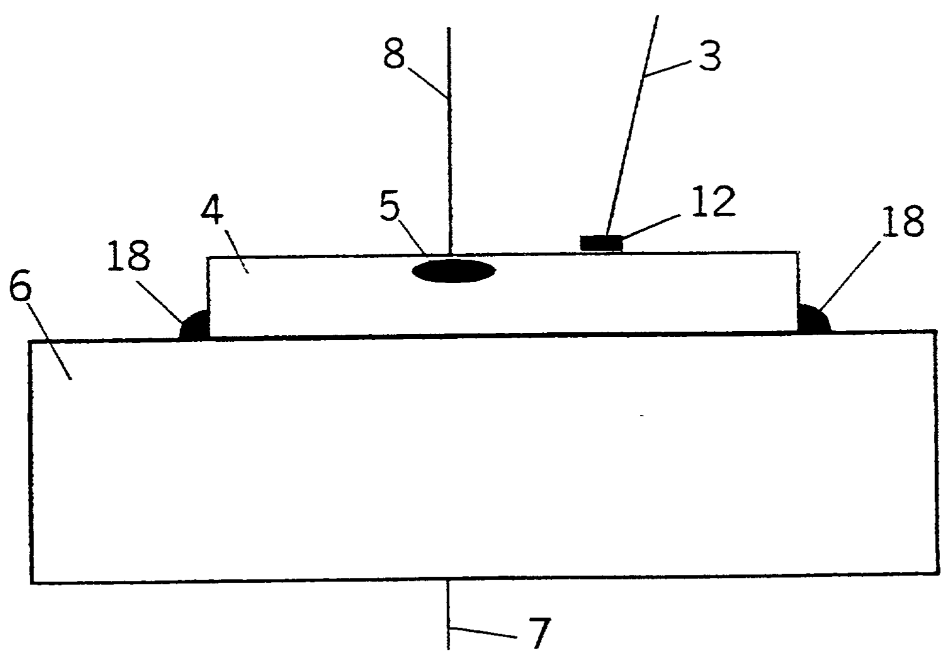

FIG. 10

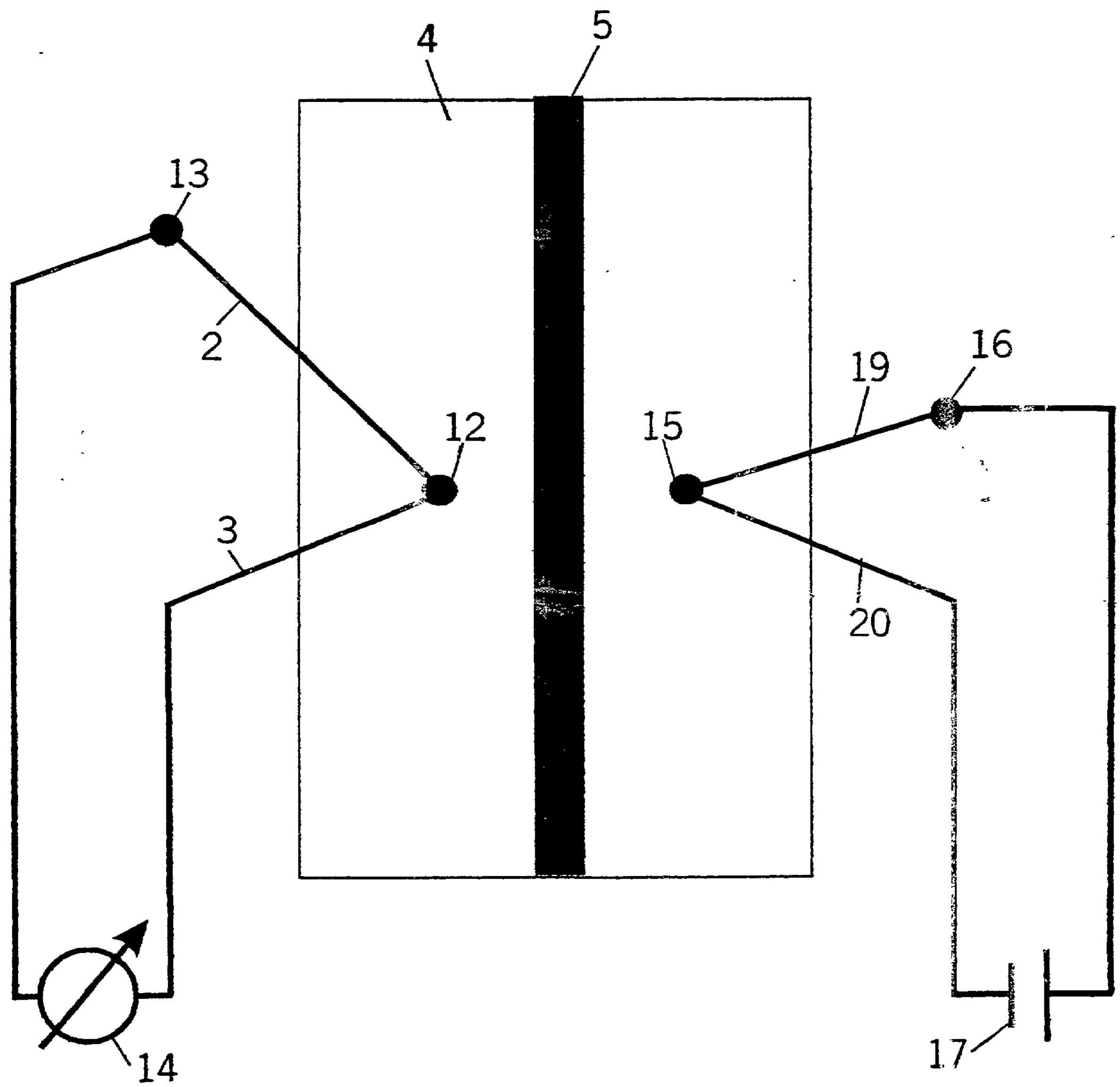

FIG. 11

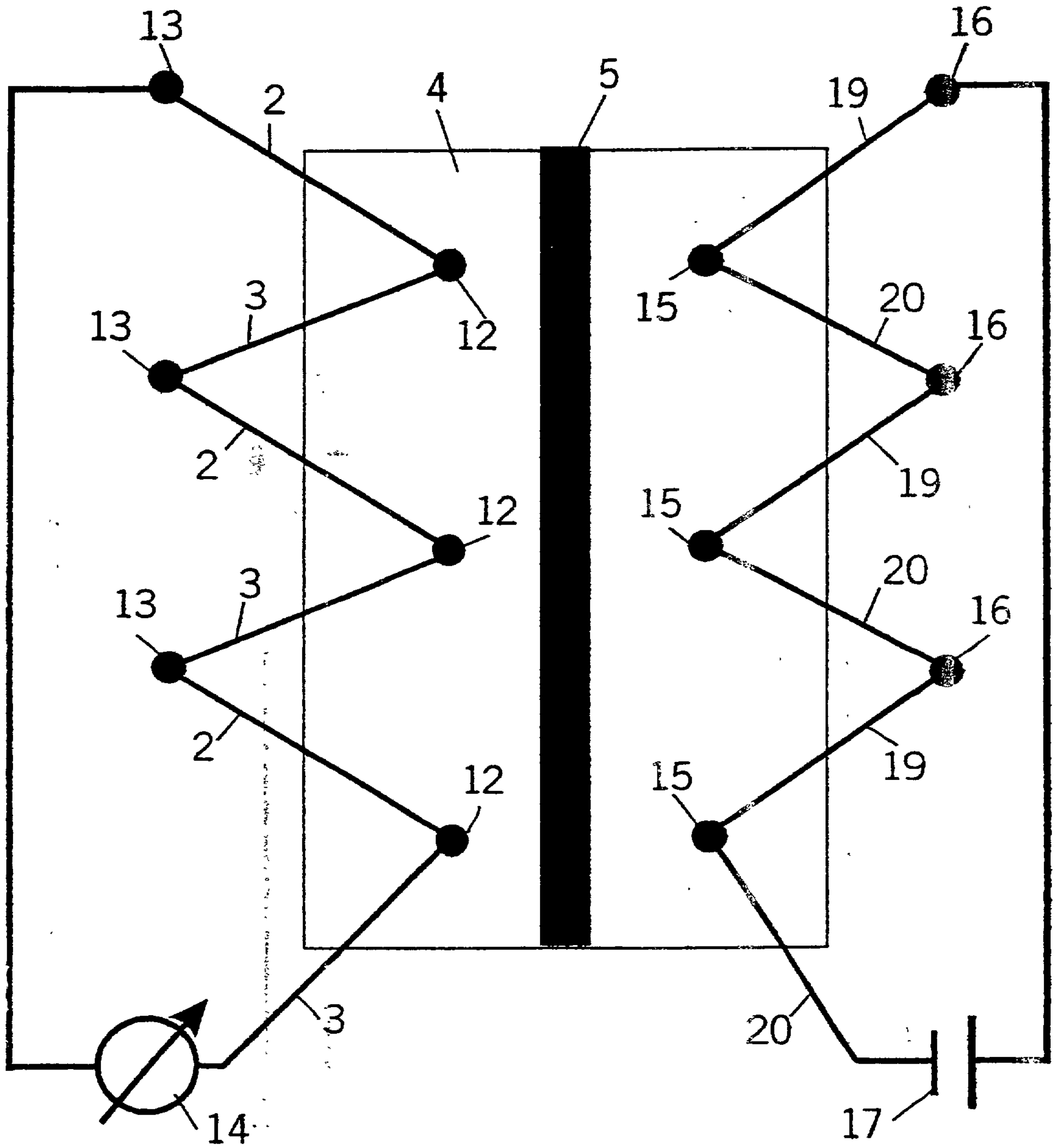

FIG. 12

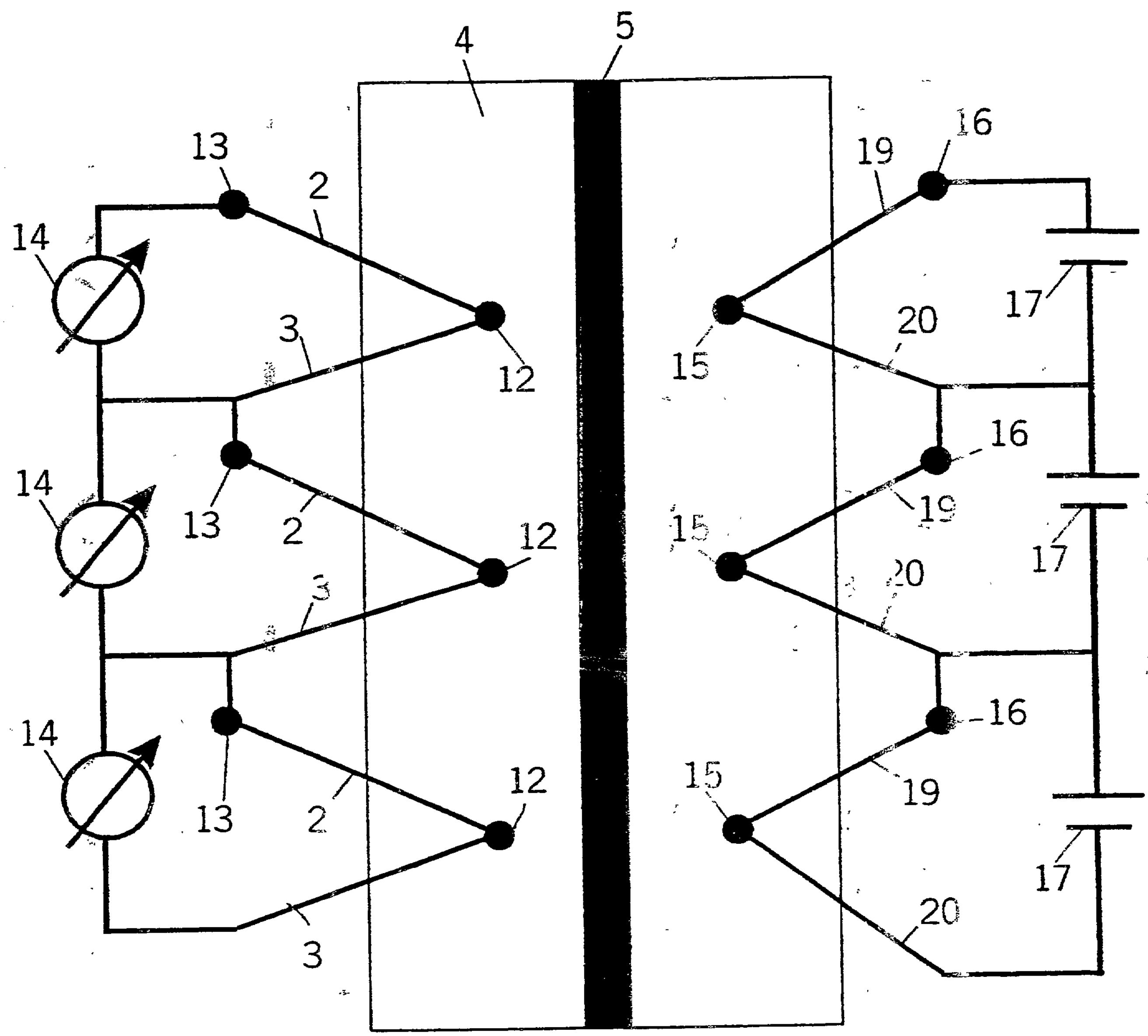

FIG. 13

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	
DECLARATION AND POWER OF ATTORNEY	ATTORNEY'S DOCKET NO. **2345/119**

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name,

I believe I am an original, first, and joint inventor of the subject matter that is claimed and for which a patent is sought on the invention entitled **SEMICONDUCTOR LASER CHIP**, the specification of which was filed as International Application No. PCT/EP98/06144 on 28 September 1998 and is filed herewith in the United States Patent and Trademark Office.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

PRIOR FOREIGN APPLICATION(S)

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. § 119
GERMANY	**197 46 204.9**	**18 Oktober 1997**		**YES**

(2) POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorneys:
Richard L. Mayer (Reg. No. 22,490)
Erik R. Swanson (Reg. No. 40,833)

SEND CORRESPONDENCE, AND DIRECT TELEPHONE CALLS TO:

Richard L. Mayer
KENYON & KENYON
One Broadway
New York, New York 10004
(212) 425-7200 (phone)
(212) 425-5288 (facsimile)

EL179106520

I declare that all statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under § 1001 of Title 18 of the United States Code and that such willful statements may jeopardize the validity of the application or any patent issuing thereon.

FULL NAME OF INVENTOR	FAMILY NAME **RICHTER**	FIRST GIVEN NAME **Hartwig**	SECOND GIVEN NAME
RESIDENCE & CITIZENSHIP	CITY & ZIP CODE **D-64291 Darmstadt**	STATE OR FOREIGN COUNTRY **Germany**	COUNTRY OF CITIZENSHIP **Germany**
POST OFFICE ADDRESS	POST OFFICE ADDRESS **Meidnerweg 12**	CITY & ZIP CODE **D-64291 Darmstadt**	STATE OR FOREIGN COUNTRY **Germany**
Signature		Date	

FULL NAME OF INVENTOR	FAMILY NAME **BECKER**	FIRST GIVEN NAME **Manfred**	SECOND GIVEN NAME
RESIDENCE & CITIZENSHIP	CITY & ZIP CODE **D-10409 Berlin**	STATE OR FOREIGN COUNTRY **Germany**	COUNTRY OF CITIZENSHIP **Germany**
POST OFFICE ADDRESS	POST OFFICE ADDRESS **Ostseestrasse 38**	CITY & ZIP CODE **D-10409 Berlin**	STATE OR FOREIGN COUNTRY **Germany**
Signature X Manfred Becker		Date 4th February 2000	

DEX

I declare that all statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under § 1001 of Title 18 of the United States Code and that such willful statements may jeopardize the validity of the application or any patent issuing thereon.

1-00

FULL NAME OF INVENTOR	FAMILY NAME **RICHTER**	FIRST GIVEN NAME **Hartwig**	SECOND GIVEN NAME
RESIDENCE & CITIZENSHIP	CITY & ZIP CODE **D-64291 Darmstadt**	STATE OR FOREIGN COUNTRY **Germany**	COUNTRY OF CITIZENSHIP **Germany** DEX
POST OFFICE ADDRESS	POST OFFICE ADDRESS **Meidnerweg 12**	CITY & ZIP CODE **D-64291 Darmstadt**	STATE OR FOREIGN COUNTRY **Germany**
Signature	X Hartwig Richter	Date	23/02/2000
FULL NAME OF INVENTOR	FAMILY NAME **BECKER**	FIRST GIVEN NAME **Manfred**	SECOND GIVEN NAME
RESIDENCE & CITIZENSHIP	CITY & ZIP CODE **D-10409 Berlin**	STATE OR FOREIGN COUNTRY **Germany**	COUNTRY OF CITIZENSHIP **Germany**
POST OFFICE ADDRESS	POST OFFICE ADDRESS **Ostseestrasse 38**	CITY & ZIP CODE **D-10409 Berlin**	STATE OR FOREIGN COUNTRY **Germany**
Signature		Date	